SANITARY HOUSES.

TWO LECTURES

TO

UILDERS AND PLUMBERS

DELIVERED IN THE HALL OF THE
ROYAL SCOTTISH SOCIETY OF ARTS, EDINBURGH,
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WITH THIRTY-FIVE ILLUSTRATIONS.

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PREFACE

The following Lectures were merely intended to bring before Plumbers and Builders some of the well-known facts of Sanitary Science which bear upon their occupations, and consequently they make little pretension to novelty. The prolonged and animated discussion to which they gave rise, as well as the requests for their publication, lead me to hope that they may be useful in a printed form. Though delivered under the auspices of the Royal Scottish Society of Arts, I am alone responsible for any erroneous statements they may contain. I would take this opportunity of expressing my acknowledgments to the Council and Secretary of the Society, and of tendering my thanks to Dr R. M. Ferguson, the President, for occupying the Chair at these Lectures, and especially for the able summary with which he opened the adjourned discussion, and the systematic method he impressed upon it.

J. A. RUSSELL.

WOODVILLE, EDINBURGH,
April, 1878.

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LECTURE I.

In two lectures it would be impossible to do more than take up a few of the points involved in the construction of healthy dwellings, and it will be unnecessary to refer particularly to arrangements suitable only for very large buildings, as their construction will usually be supervised by some one skilled in sanitary matters ; nor shall I waste time in alluding to many sanitary patents, because I am convinced that the great majority of them are either utterly useless or require the care of an engineer to make them work.

The Site

of a house is seldom a matter of choice, but as the position of the various rooms may be arranged at will, it is well to know that, taking into consideration the amount of sun and rain, a south-east aspect is, generally speaking, the best for windows and living rooms, while the south-west is least desirable. Staircases, larders, and rooms of least importance may face the north. A north aspect is to be preferred for artists' studios, consulting rooms, engravers' and microscopists' work-rooms, on account of the steadiness of the light from that quarter of the sky. It is important that the ground under the house and immediately around it should be free from vegetable or animal matter, which could decay and give off deleterious gases.

The rain which falls upon the earth is largely absorbed, and must then either be evaporated from the surface or be carried off by deep channels. Our object is to have it removed in the latter way as rapidly as possible, and consequently the subsoil should be rendered dry and warm by

deep drains, which may prevent the ground water from rising beyond a fixed level. It has been found that drained land has a mean summer temperature from 1 to 3 degrees higher than undrained. Wet soil carries away heat much more quickly than dry, and so renders a basement flat cold, but the principal cause of the cold felt on damp soils is the great evaporation from them. More water will evaporate from a wet solid substance than from the surface of water itself, and water in passing from the liquid form to the state of gas absorbs an enormous quantity of heat, which it takes from surrounding objects. To convert a pound weight of water into vapour requires more than five times as much heat as would be needed to make a pound of ice-cold water boil. The whole of this heat disappears, for it is spent in converting liquid water into gaseous water of the same temperature. Cold is, however, only one of the evil results of evaporation from damp soil. The vapour carries up many undesirable things with it into the air. "Even animals of some magnitude are lifted by the ascensional force of evaporation from the surface of marsh water" (Parkes).

The place where this cold acts, viz., the floor, is not a matter of indifference. I believe that cold applied only to one part of the body, and especially when that part is the feet, is more dangerous than a uniformly cold atmosphere surrounding us, and that many internal inflammations are set up by disordered action of the nervous system caused by the local application of cold.

The vapour of water attaches to itself any decomposing organic vapour in the air, and seems to increase its noxious qualities. At all events we know that organic matters are more readily perceived by the sense of smell in damp air, and that what we may call the germs or ferments of disease lose much of their power in dry air, and prove most virulent in presence of moisture. So long ago as 1830–36, in the "Naval Reports," frequent washing of the lower decks of ships was credited with causing catarrhal and rheumatic affections, inflammatory affections of the lower extremities, reduced physical force, and diseases of debility. Beeswax and dry rubbing of floors is now used as far as possible in hospitals,

to avoid the increased risk of erysipelas and hospital gangrene due to frequent washing. It is said that the unhealthiness of Valetta, in Malta, is due not merely to the saturation of the porous rock with filth from the gutters cut in it, but to the daily washings of the absorbent stone floors.

Ground Air and Ground Water.—The earth contains a large amount of air and usually water at a variable depth. The level of the latter has been much investigated on the Continent. It is found that when the level of the ground water falls air is sucked into the earth, and again as the level rises any gases in the earth are to a large extent expelled. In fact, the earth may be said to breathe, and during expiration to send out gases more or less noxious. Ground air always contains much carbonic acid, which is deleterious to us, and it is often contaminated with still more objectionable gases. It is consequently an object to prevent ground water from ever rising to any great extent after rainy weather. Another benefit resulting from drainage is that earth dried in this way gains a very great power of destroying any putrid matter which may get into it, a circumstance of which advantage is taken in purifying sewage by land.

The proof that all this is not mere theory as regards the effect upon health is to be found in the death-rates of towns on wet and dry soils, and still more strikingly in a comparison of the death-rates of towns before and after being drained. The death-rate from consumption especially is lowered in an extraordinary degree by draining a wet subsoil. Mr Simon, in his report to the Privy Council, March 1868, gives a list of towns that had benefited by drainage, from which a few may be quoted.

Death-Rates by Phthisis fallen per cent. after Drainage.

Salisbury,	49	Leicester,	32
Ely,	47	Cheltenham,	26
Banbury,	41	Bristol,	22

The effect of damp soil in causing consumption was suspected twenty years ago by Dr Bowditch of Boston,

and proclaimed by him in 1862 as a fact with regard to Massachusetts, but the full statistical proof was not forthcoming till the reports of Dr Buchanan, medical officer of the Privy Council, appeared in 1866 and 1867. Rheumatism and heart disease are, next to consumption, the diseases most affected by drainage.

The depth and number of the land-drains required to dry the subsoil will vary with its character, but they cannot be placed where the solidity of the earth bearing the walls might be shaken. Water will rise a long way in chalk by capillary attraction, but only a very short distance in sand. Clay requires many drains from its retentive properties, while one may be enough in gravel. In any case the subsoil water should be at least three feet below the foundations. These drains, like all others, should have no blind ends, and should be arranged so as to admit and discharge air freely, and consequently have a circulation of pure air through them. They must on no account communicate directly with a sewer, or there will be a danger of sewage gas passing back and saturating the soil.

Isolation.—Even with a well-drained subsoil it is necessary to isolate the walls and rooms from it. This may be best accomplished by a well-ventilated air space or cellar below the house with ashes or charcoal upon the floor, or by a concrete bed stretching across from outside wall to outside wall. The walls may have concrete foundations, and must have damp-proof courses of some impervious material to prevent damp rising in them. Slate and cement, or asphalte, or, perhaps better, vitrified tiles with ventilating holes, are used. The outside of walls, below the level of the ground, should be separated from it by a space or area. The necessity for the complete isolation of the dwelling from the ground is obvious if we remember that water vapour, coal gas, and sewage gas are all lighter than air, and so tend to ascend into the dwelling and pass through barriers by diffusion, which is a property greatly influenced as

Fig. 1.
Ventilating Damp proof Course. James Stiff & Sons, Lambeth.

to rapidity by lightness. They are, moreover, sucked up by the action of the fires and warm air within the house.

Coal Gas.—The danger from coal gas is no imaginary one. Only the other day we had a serious explosion in our new water pipes, due to gas finding its way from the soil into the pipes. In London in 1874, a house was blown up by a coal gas explosion, though no gas was laid on; and Pettenkofer tells of a family killed by gas that had traversed twenty feet of earth from the nearest pipe to reach the house. A gentleman from Berwick-on-Tweed tells me that, some years ago their water supply ran short, and the pipes being at times half empty took in gas from the ground to such an extent that it would take fire on applying a light to the water tap. This evil is aggravated by asphalting and paving streets, for it then travels in an erratic way, *e.g.*, to a dwelling-house behind a shop without appearing in the shop.

Portland Cement.—In order to test the efficacy of Portland cement as an insulator, I have here a cylinder two inches in length, composed of two parts sand and one part cement bedded in a glass funnel, and coated with paraffin, with the tip of the funnel dipping in mercury within an air-tight vessel. You observe that an aspiratory force equal to one inch of mercury brings air through it slowly, while a suction equal to seven inches gives a tolerably rapid succession of bubbles.

Removal of Waste.

The waste material to be removed from a house includes water from baths and soapy water, only moderately foul, as well as the more polluted discharges from kitchen sinks and water closets. It is believed that perfectly fresh excreta, unless they contain the seeds of some special disease, such as smallpox or scarlet fever, only become dangerous after the lapse of a little time, when they have begun to decompose, *e.g.*, the fresh odour in a closet is not dangerous, but unless removed by immediate ventilation it becomes hurtful in a short time. Our arrangements then should cause the immediate and complete removal of all excreta from within

the house, so that not even a vapour would be left behind. In one hour after being thrown into a fitting it should be more than two miles away. An eminent authority, Dr Carpenter of Croydon, has pointed out that the agricultural value of sewage for farming is very much less after its age ceases to be measured by hours.

The difficulty we have to face is that some adheres to the inside of pipes, and forms deposits in traps or bends, where it acts as a ferment initiating putrefactive change in the next charge that passes along, and generates gases which often defy efforts to keep them from escaping into the house if allowed to exist in the pipes. House drainage has therefore become virtually a battle with sewage gas.

The effects of this gas vary with its exact composition, the dose, and strength and age of the patient. It affects children specially, making them pale and languid, and causing loss of appetite and diarrhœa (Parkes). A large dose, received from clearing out a privy at Clapham, produced in twenty-three children violent vomiting and purging, headache, prostration, and convulsions of the muscles, so that two of them died in twenty-four hours. Older persons have had headache, languor, want of appeitite, and attacks of fever or mere feverishness, and some degree of anæmia, *i.e.*, want of blood. Carpenter says, "The bilious headaches and sick attacks of cooks are frequently caused by foul air rising from the kitchen sink. It unfortunately happens that it is not the decided stink that is most dangerous; the results of putrefaction are not nearly so fatal as those faint animal odours that indicate organic matter in a state of change; a good stink rectifies itself by compelling ventilation." Though sewage gas may produce any effect from simple languor up to death, undoubtedly its most serious action is that of preparing our bodies for the onset of specific diseases. Under its influence we become like well-cultivated land, only waiting the arrival of the seeds of diphtheria, typhoid fever, scarlet fever and such like, to take them in the most virulent form, and in many cases this gas not only prepares the soil but carries the seed to it.

The experiments upon cement and mortar, by which air is drawn through them, show how hopeless it is to try to confine

sewage gas in pipes jointed with these materials. I do not suppose that any one would attempt it with a brick or stone drain. In support of these experiments, I quote the following from Mr Philbrick's excellent common sense article on house drainage in the Massachusetts State Board of Health Report, January 1876 (p. 437), which I would gladly see reprinted separately in this country.

"The writer has seen such a drain, well laid with Scotch pipe and full cement joints, and covered with concrete of hydraulic cement on the cellar floor, giving off through this cement an amount of stench that made the cellar nauseous, even though the soil pipe above was ventilated. The sewer in the street may have been in fault, but this case serves to show how penetrating are these gases, and that good hydraulic cement mortar, though impervious to water, is not impervious to them. A ventilated trap outside the house afterwards stopped this nuisance in the case referred to; but even this may not be enough in all cases, for a certain amount of slime inevitably collects upon the insides of house drains themselves, which, by its decomposition, evolves gases requiring metal joints to hold them."

We may lay it down as a principle that, except for a few seconds immediately after the discharge into it of the contents of a fitting, no pipe should contain anything but fresh air in a state of motion, and no trap should contain anything but pure water. To attain this, the pipes must have no blind ends, but open freely to the external air at both extremities; and if the water-closet, sink, or other fitting be so far from the fall pipe that a branch is needed, then a ventilating pipe must go from immediately outside the water trap to the external air. It should be an object to keep down the number, complexity, and size of pipes as much as possible. If we wish to get rid of a body of water, we may either send it slowly through a large pipe or rush it full bore under a good head of pressure through a small one. The latter, when practicable, is certainly best; for there is less chance of sediment, less wet surface to evaporate, and smaller joints to make tight. As it is so difficult to make joints tight, we are led to diminish their number and size by having our

pipes of metal in long lengths, soldered together when lead is used, or leaded, calked, and painted when iron is the material employed.

Here again we have the danger pointed out by Dr Fergus of Glasgow, that lead is perforated by sewage gas. We hardly ever see these pock marks and perforations on the part of the pipe touched by the water, but only on that portion exposed to the gas. The action is analogous to that by which white lead is made in the old-fashioned way, by hanging a piece of lead in a jar containing a little vinegar, and packed in stable manure. In both cases carbonate of lead is the result. On the table is a selection from Dr Fergus' well-known specimens kindly lent for the evening. Each one of them has been associated with one or more cases of disease. An inspection shows that the solder has nothing to do with the corrosion which is most frequently found on the upper side of horizontal lengths in upper flats.

These circumstances teach us that all waste pipes should pass outside as soon as possible, and that consequently all sinks and water-closets should be near an outer wall. Water-closets are best placed in a detached turret or structure separated from the house by a passage having cross ventilation. Whenever a pipe of any kind must pass horizontally under a floor, its course should be covered by a flooring plank fastened down with brass screw-nails, which will indicate the plank, and allow it to be raised easily. It is undesirable to bring a pipe or drain along the basement from back to front; still in many cases, as in Eton Terrace here, it must be done. It is usually recommended that in such a case the pipe should be of stoneware embedded in concrete. This conceals the pipe, and prevents getting at it, and in houses like those in Eton Terrace would involve 14 or 15 joints. A cast-iron pipe would require only two or three joints, and if placed above the floor, as it should be, could always be inspected. Indeed, many of the best plumbers and engineers, both in this country and America, prefer iron pipes to lead in almost all situations. The expansion or contraction of cast iron between 32° F. and 212° F. is only ·0011, while that of lead is nearly three times as great (·0028), making it difficult to preserve

tight joints, and prevent branches from cracking where they bend with each change in the length of the main pipe. There is some little difficulty in obtaining iron pipes strong enough to stand the leading and battening of the joints, but this could easily be overcome by making the ends thicker at spigot and faucet. When lead waste-pipes enter iron ones, "the only proper way to make such a joint is to solder a tinned iron or brass ferrule to the outside of the lead pipe which is to enter the bell of the iron pipe. This ferrule gives a stiff material, against which a lead joint can be calked in the same way as between two pieces of iron pipe" (Philbrick).

The contents of water-closet soil-pipes should, if possible, be the last to join, and bath-wastes the first. It is generally directed that bath and other wastes of a similar kind discharge in the open air over a grating upon a trapped gully connected with the drain * (see fig. 2); but when, as in so many houses, the bath and water-closet are placed side by side in one room, it would be as safe if the bath-waste poured into the basin of the water-closet, provided the latter has no valve or pan. This would flush the soil-pipe, and concentrate labour and attention upon one pipe, and so help to secure that careful and good workmanship, without which no scheme will avail.

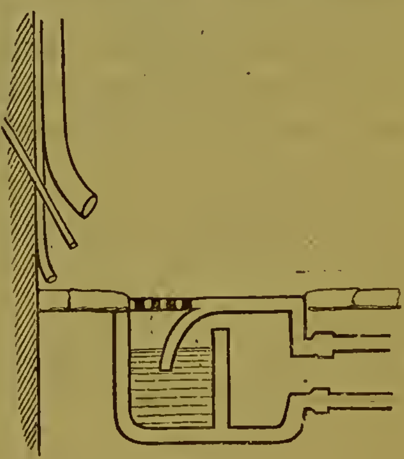

Fig 2.

Flushing and Disinfecting.—To prescribe flushing and disinfectants in ordinary circumstances is merely to confess failure. Proper pipes, with sufficient fall, flush themselves in the ordinary discharge of their duty, and should not require disinfection. The excreta from cases of infectious disease require a very large quantity of disinfectant, which should be applied in a concentrated form before they are thrown into the house

* The meaning of the word drain has been altered by a recent English Act. It now means the channel communicating between one building or premises and a sewer or cesspool. Sewer is the channel draining two or more buildings or premises occupied by different persons.

pipes. When a reliable amount of disinfectant is in these cases sent down the pipes, it is apt to corrode them, unless it has been allowed to expend its energy on the excreta alone in the first place. To give an idea of the expense and quantity required, I may state that an ordinary dejection from a typhoid patient requires to be mixed with about *twelve* times its volume of Condy's fluid for perfect safety, should that popular disinfectant be the one chosen. If small quantities of disinfectants are sent down water-closets, it is better to mix them with the after-flush water, which fills traps and basins, so that the little energy available may be devoted to the destruction of any slime adhering or portions of organic matter retained. The crust in containers and pipes consists partly of salts and partly of living matter showing extremely small round bodies and rods under the microscope.

To prevent sediment in pipes, T joints are to be avoided and junctions effected by curved Y joints though a little more expensive, and smaller pipes should branch into larger ones. The following table of velocities is from Mr Bailey Denton's work on *Sanitary Engineering* :—

Diameter of Pipe.	270 Ft. per Minute, 4½ Ft. per Second.		360 Ft. per Minute, 6 Ft. per Second.		540 Ft. per Minute, 9 Ft. per Second.	
Inches.	Fall.	Gallons per Minute.	Fall.	Gallons per Minute.	Fall.	Gallons per Minute.
3	1 in 30·4	81·0	1 in 17·2	108	1 in 7·6	162
4	1 in 40·8	144·0	1 in 23·0	192	1 in 10·2	288
6	1 in 61·2	324·0	1 in 34·5	432	1 in 15·3	648
9	1 in 92·0	742·5	1 in 51·7	990	1 in 23·0	1485

The Drain or private communicating sewer leads from the house pipes to the sewer or cesspool, and on the way may take up the ground water collected by the land drains for drying the subsoil. The arrangement for disconnecting the house system is placed at the commencement of the drain or somewhere on its course. It is usually made of glazed stoneware

pipes joined with hydraulic cement. Mr Beatson, Burgh Surveyor for Leith, among many other sanitary improvements, has introduced the practice of putting together three pieces in a vertical position so as to make a long length before laying. In this way he makes sure that at the worst only every fourth joint can be doubtful. Mr Eassie states that the best fall is 2¾ or 3 inches in 10 feet. No engineer of reputation makes the drain of an ordinary building more than 6 inches diameter.

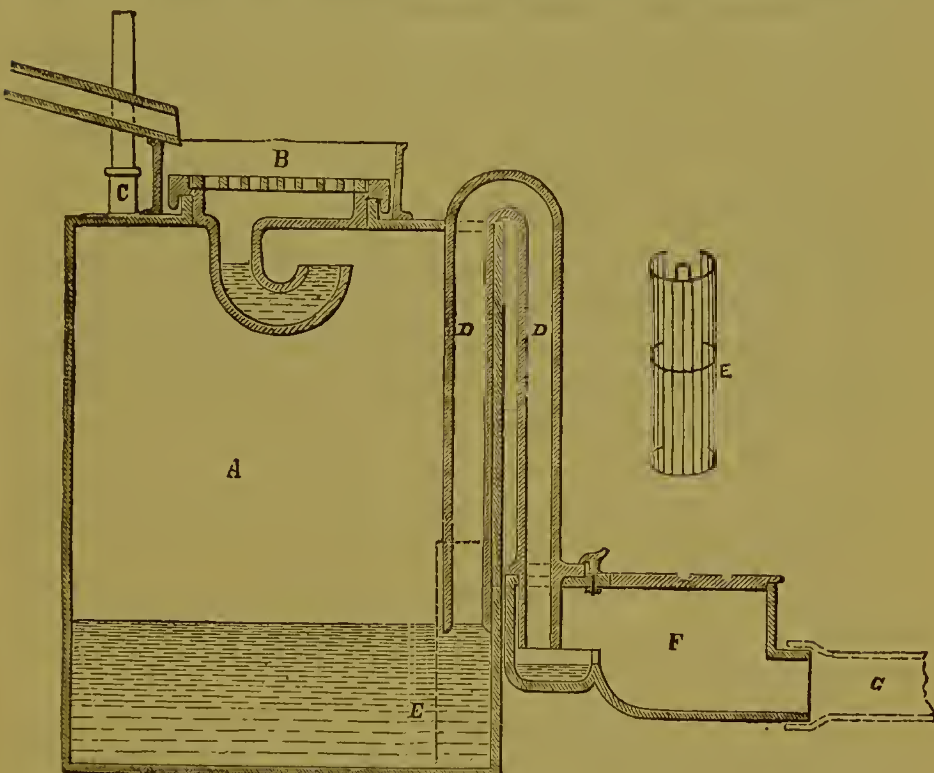

Fig. 3.—Field's Flush Tank.

Mr Philbrick says, "Drains are not intended to carry broken crockery, old clothing, rags, or shoes. Such things are often found in them, it is true; but increasing the size of the drain is no remedy for such abuse, which would choke a street sewer. On the other hand, the smaller the drain which will carry the largest flow with which it is likely to be taxed, the better is the scour, and the more likely it is to keep clean. With a fall of two feet or more in 100 feet of length, a four-inch pipe is better than a larger one for a house drain used by some fifty persons, because with this limited flow the small one would scour better than the larger one. If rain water is admitted

from the roof gutters, a larger size is perhaps needed, but six inches is ample, even then, for any ordinary house-roof. For hotels and large establishments, containing many receptacles for sewage and many branch drains, a six-inch pipe would be ample, unless rain-water be admitted from extensive roof surfaces.

"When being laid, a swab should always be drawn through them, to wipe the surplus cement from the joint on the inside, every new piece put into the trench being strung on to the line or rattan which carries the swab, and draws it along. The writer has seen a good drain, which would otherwise have been successful, entirely choked by sewage accumulating against those burrs of cement inside the joints, which should have been wiped out when laid."

When sufficient fall cannot be had for the drain, regular flushing is required. Mr Rogers Fields' siphon flush tank is an admirable contrivance for accomplishing this by means of the slop water which it collects till the tank is full, and then suddenly discharges into the drain. It is also a very good grease trap for the kitchen water to pass through.

Traps are usually placed either outside the house at the commencement of the drain, to act as barriers against the entrance of gas from the sewers, or within the house close to a fitting of any kind, to prevent gas escaping from the pipe and entering the air of the house.

(*a.*) All traps should be completely self-cleansing, and consequently should cause no abrupt change in the direction of flow. Square traps, or those with corners, sharp edges, and very quick bends, are not so good as simple S bends.

(*b.*) Traps should usually contain nothing except pure water, and consequently clean water should be sent down after foul to fill the traps.

(*c.*) They should not be deep in the midfeather, or in water seal, because solids will bob about upon the proximal side till they begin to putrefy and break down, if the water seal is too deep. This is a very common fault. A water seal of not less than $\frac{3}{4}$ inch nor more than $1\frac{1}{2}$ inch is looked upon as best. Probably $1\frac{1}{2}$ inch is too much. The practical men of most repute seldom give a greater seal than 1 inch in the traps

below water closets. Any one who believes in deep traps should take one and weight some bottle corks till they float low, and then try to pass them through the trap with a pitcher of water. By the time he has drawn twenty or thirty pitchers full he will probably have formed a new opinion. When a bad odour is felt at the disconnecting opening at foot of the soil pipe, it is often due to putrefaction in the water-closet trap, and can generally be prevented by attending to that trap, or as some do by taking it away altogether.

The defects of traps are numerous.

1*st*, A very common one is bad laying, which may do away with the seal altogether.

2*d*, In traps with a very easy bend and a quick fall into them, the water may be carried by its own momentum out of the trap into the pipe beyond, sufficiently to unseal the trap. A gentle after-flush will correct this.

3*d*, A good trap, on account of its small water seal, is easily forced by increased pressure on the distal or drain side. This pressure may be due to generation of gas, or to heat causing expansion of gas, or most frequently to the wind blowing into the pipe. The remedy is to allow the increased tension expend itself through a ventilating pipe, and put wind-guards over openings. A three-inch water seal is no protection against this evil, as may be shown by a simple experiment. A piece of glass tube is bent to form a trap with three or four inches of water seal, and one end passed through the cork of a glass flask. The heat of the hands laid upon the flask will cause sufficient expansion of the air in it to blow the water out of the trap.

4*th*, The water evaporates if the pipe is long unused. This cannot happen to the disconnecting trap unless the house is uninhabited, and at the same time no rain falls.

5*th*, The trap may be unsiphoned if the pipe beyond runs full bore. The remedy is to have a ventilating inlet joining the highest part of the bend on the distal side of the trap. This ventilating pipe may either come from the soil pipe considerably higher up (fig. 4), or preferably from a separate air pipe (fig. 5), or in many cases from a grating to the open air.

6*th*, Traps may be unsiphoned by a body of water coming

down the soil pipe from a fitting higher up on the same stack. Such a body of water will act like a piston, compressing the air in front of it, and making suction behind it. One gallon of water fills nearly 39¼ inches of 3 inch pipe, 28·8 of 3½-inch, 22 of 4-inch, and 17·43 of 4½-inch.

The remedy for this is the same as in the last case, and if the vent be taken from the soil-pipe higher up, the above data will indicate the proper distance. Valve water-closet traps are least liable to this defect.

7*th*, The water in traps may be said to be to some extent pervious to gases, for it absorbs them on the one side and discharges them on the other. Dr Fergus of Glasgow, who first drew attention to this defect in traps, has discovered that small streams of gas pass through in a manner characteristic for each gas before the water is saturated, provided the trap be of wide bore.

(Dr Fergus' experiments with ammonia, chlorine, sulphuretted hydrogen, &c., were repeated before the audience.)

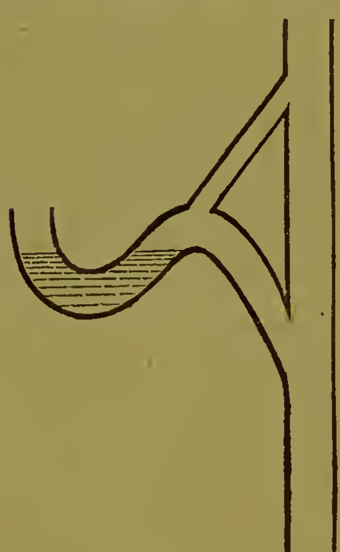

Fig. 4.

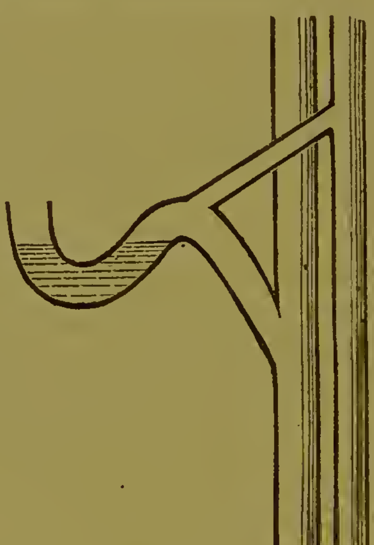

Fig. 5.

Disconnectors are traps intended to prevent the gases generated within the public sewers from gaining admission to the system of house pipes or land drains. They are very important. A disconnector should consist of a water seal shutting up the channel of the pipe against sewage gas, and

of a ventilating opening to discharge any gas that may make its way through the seal. In addition, many disconnectors provide for the ventilation of the drain or sewer beyond the trap, and for the admission or discharge of air from the foot of the soil or waste pipe. Some disconnectors are suited for

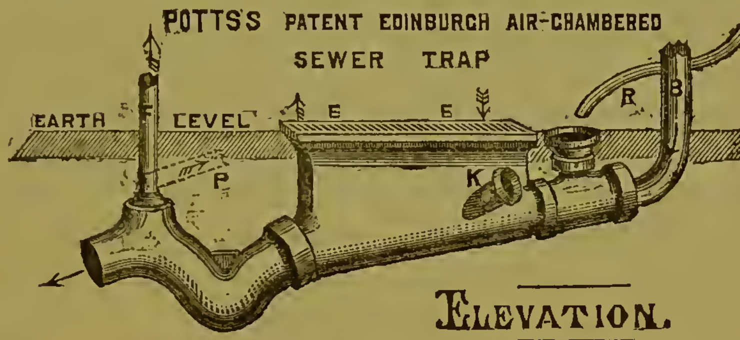

Fig. 6.—Elevation.

receiving all kinds of wastes; others are suited to receive only pipes containing the purer waste waters from baths, &c. When these discharge in the open air over a grating splashing often results, which is avoided by leading them into a discon-

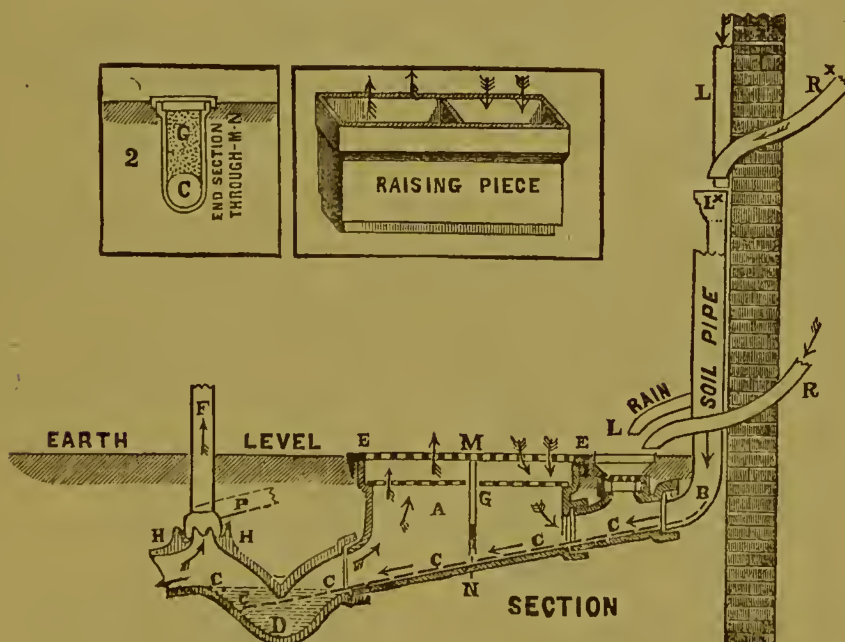

Fig 7.—Section.

necting trap. Certain makers of the latter kind sell them for application to water-closet soil pipes as well. Disconnectors should always be outside the dwelling, and I think that it is

only in exceptional cases they should be used for ventilating the drain beyond, as this can usually be better accomplished otherwise.

For shutting off bad sewers I am inclined to assign the first place to the disconnecting trap (figs. 6 and 7) made by Mr Potts of Handsworth, near Birmingham, as conforming to more of the requirements of a good trap than any other which I know. It makes provision for ventilating the drain if desired on the distal side, has a good form, a water seal not too deep, and separate openings for discharging foul air which may pass the seal, and for admitting air to the soil-pipe foot. It receives rain water and all wastes. The disadvantages are a price rather high for small houses and an unwieldy size.

For good, clean, well-ventilated sewers Potts' trap might be

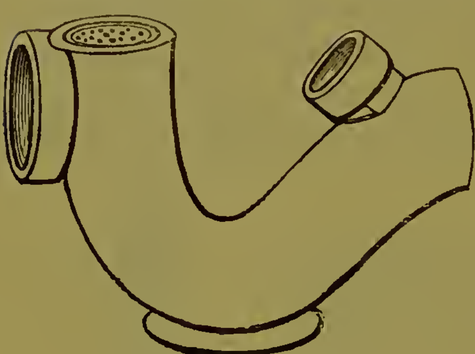

Fig. 8.—Elevation.

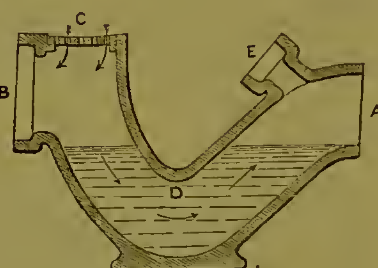

Fig. 9.—Section.

reduced in length, or Mr Weaver's ventilated siphon trap (figs. 8 and 9) may be used. In the latter there is only one opening for discharging gas that has passed the water seal and ventilating the soil-pipe. It is a good trap, is cheap, and economises space.

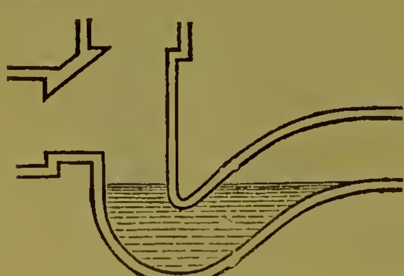

Fig. 10.

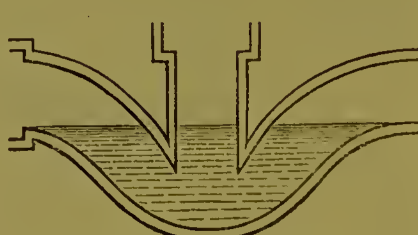

Fig. 11.

Mr Buchan, plumber, Glasgow, has invented a good discon-

nector, figured above (fig. 10). Here there is also only a single opening for both discharge of gas and soil pipe ventilation. The proximal limb is so straight that the bottom can be reached by hand to remove any obstruction, which is less likely to occur on account of the sharper fall than in the old-fashioned non-ventilating siphon bend with cleansing eye (fig. 11).

The registered "intercepter" sewer air-trap of Messrs Stiff & Sons, Lambeth, who also make Weaver's trap, is, on account of its great depth of seal, not so well suited for a place at the

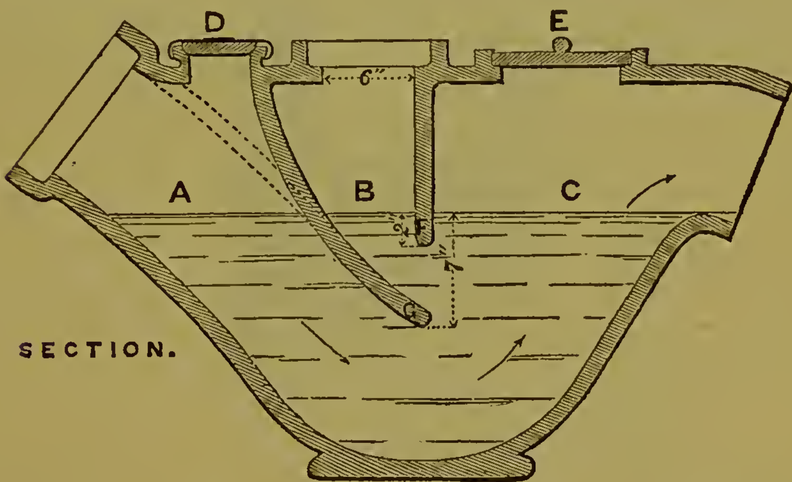

Fig. 12.

junction of the house pipes and drains as for a position at the junction of drain and public sewer, and then the drain should be freely ventilated by other means.

Various modifications of a double trap are coming into use

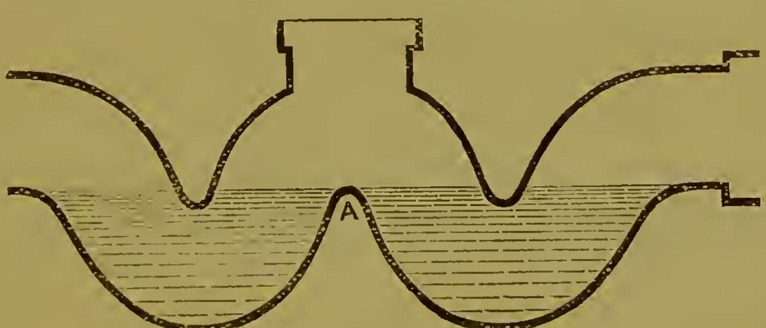

Fig. 13.

in Edinburgh. It is usually made of two simple pipe bends joined at A, opposite which is a large ventilating opening to a manhole or pipe. Sometimes the distal trap is lower than the proximal one, placed to the right in the figure; at other times

they are separated by a bit of pipe. Separate ventilating openings for drain and soil-pipe have to be provided on either side of the double trap. It is cheap, and permits of ready inspection and the application of tests to the pipes, but is unwieldy, and has two reservoirs where sewage may putrefy, and unless one trap be lower than the other, the flow is less rapid than in simpler arrangements.

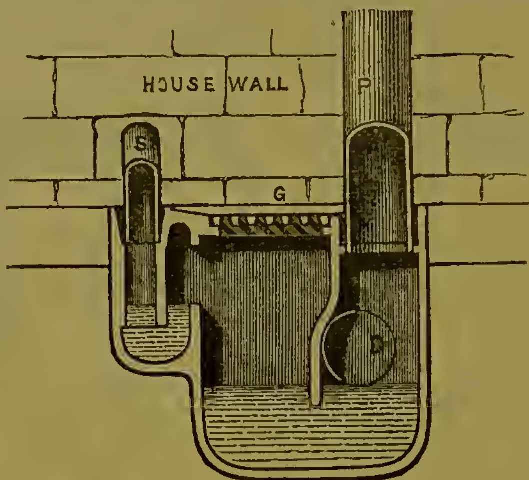

Fig. 14.

Mansergh's trap (fig. 14) is a double trap, with ventilator P for the drain on the distal side and a grating ventilator between the two traps, down which yard water may be sent, while S, the kitchen-sink pipe or bath-waste, enters the proximal or nearest trap. It is a good enough grease-trap, but the changes in the direction of motion are too abrupt. It is not adapted for water-closet soil-pipes.

Water-Closets.

I am not aware of any investigation to discover the best shape of basin or the best form of trap.

The simplest form is that of a siphon-trap with the proximal end dilated into a bowl or basin, as we have it in Hopper closets, but this offends the sense of sight.

The solids should fall into water, to prevent sticking to the earthenware, and consequently the deepest water should be opposite a point one-third along the line from back to front of the opening in the seat.

Such closets as the specimen on the table sent by Mr Dodds of Thomas Street, Liverpool, where there is a separate basin, are a great improvement upon the simple siphon. Here there is nothing to offend the eye, for the outlet is invisible, being placed in front, where it permits the urine to pass directly into the trap. On this account this closet is well suited for ladies' waiting-rooms. Somewhat similar closets are made by many manufacturers. I regret that, with the exception of Jennings' original pattern, I am unable to speak of their working from personal observation. I have seen that of Mr Dodds and others tested in showrooms, but of course this is different

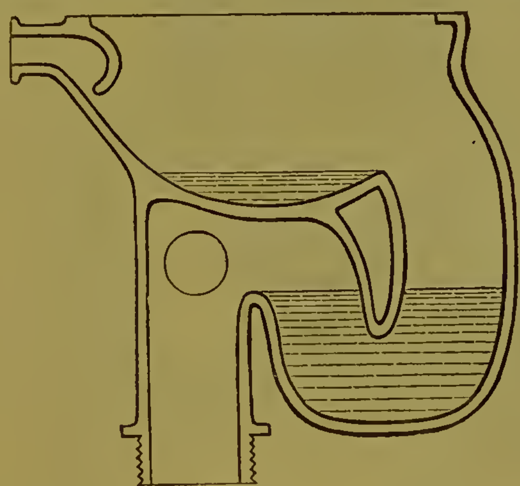

Fig. 15.
Dia rammatic Section of Dodds' Patent Closet in one piece of earthenware, with ventilating opening and ferrule.

from examining them after some months of real work. Most others have the outlet at back, and the working of the original pattern Jennings is not good. An improved pattern is now made by him. I like the appearance and working of the Dodds closet so far as I have seen it. The ventilating socket compels attention to an important point, and is in the most effective place.

The defect of this class of closet is that there is a difficulty in driving the excreta at once out of the basin into the trap, and a still greater in promptly and thoroughly clearing the trap. Evidently a large water supply pipe is necessary. For "Hopper" closets Philbrick recommends a two to two and a

half inch supply pipe, and Dodds uses a pipe of one and a half inch diameter.

If this class of closet can be made to work satisfactorily, it has advantages over any other.

The closets in most common use have a body of water maintained in the basin above the trap by either a valve or pan. This water receives the excreta, and is then, by withdrawing the valve or pan, allowed to fall suddenly into the trap, driving the contents before it.

The ordinary valve closet has a valve working in a space between the basin and the water of the trap, called the trunk or container or receiver. The valve is either made tight by india-rubber or ground to its seat, as in the Bramah closet. The basin may contain up to two or three gallons of water, and an additional quantity is let down from the cistern on raising the handle, so that the amount of water used is large.

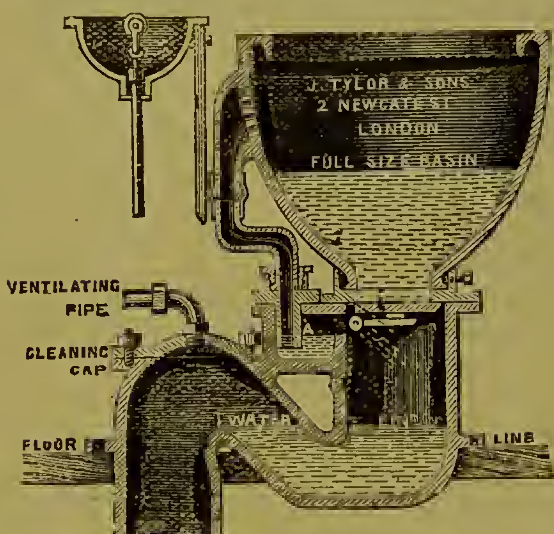

Fig. 16.

These closets are expensive and delicate, for it is obvious that a little dirt would impair the tight-fitting of the valve, and gradually empty the basin. They require an overflow, as seen on the left of fig. 16, in case of slops being poured into the basin without the handle being raised, or the supply valve leaking. The patent regulator valve closet of

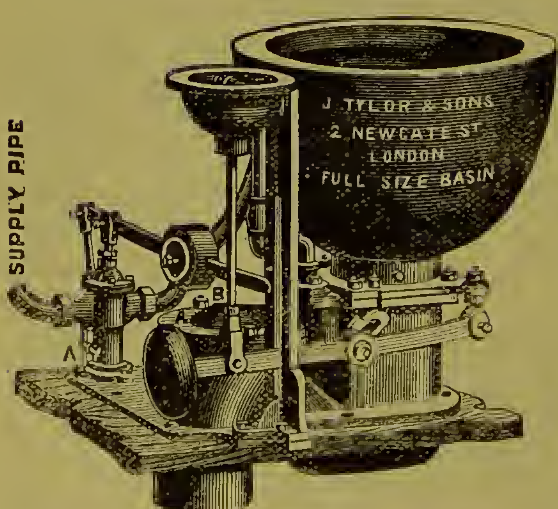

Fig. 17.

Messrs J. Tylor & Sons, figured above, is a good form. Its defects are want of ventilation of the trunk, and the small size of the ventilating pipe on the distal side of the trap. The trunk should be as small as possible, and be ventilated by one, or preferably by two pipes passing through the wall to the open air.

The trunk becomes filled with gas given off by the slime which adheres to its sides and by the water in the trap, and this gas is discharged into the house when the handle is raised, or escapes more slowly by the opening for the valve-pin, which is, however, ground into its hole in good work. In the pattern made by one well-known maker, the empty space in the trunk is about

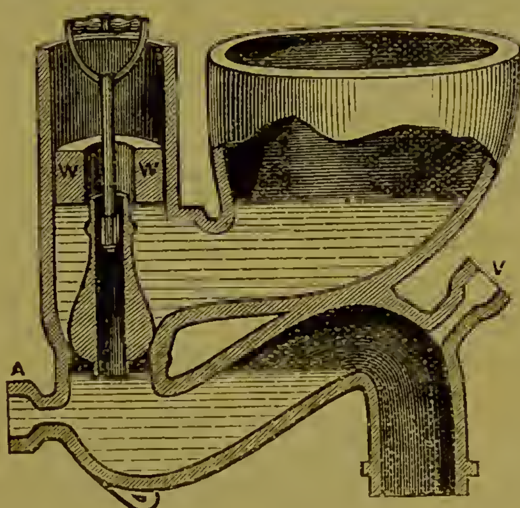

Fig. 18.

130 cubic inches. It is a mistake to speak of such closets as being "double trapped," while there is a hole in the trunk for the valve-pin, and space in it for gases to accumulate and pass up when the valve is lowered.

Mr Jennings has almost abolished this space in his patent closet by placing the valve in a side basin, and making the valve hollow to act as overflow (fig. 18). The hollow plug-valve allows any gas to escape, and the ventilator on the distal side is too small; but notwithstanding these effects it has been found a first-rate closet. Owing to the shape and size of the basin, a slimy growth may form on it, and require to be wiped off by hand.

Mr Pearson, Mr Banner, and Mr Jennings have introduced

closets without siphon traps below them. This I look upon as a reaction against the excessive depth of traps under most closets, which allows some organic matter to remain till it putrefies and dissolves. The theory is that the large volume of water rushing down the pipe draws air after it from the house, instead of allowing any ingress of gas.

The pan closet (fig. 19) so often condemned by sanitary writers is still a favourite on account of its cheapness (about one-third the price of a valve closet), its comparative freedom

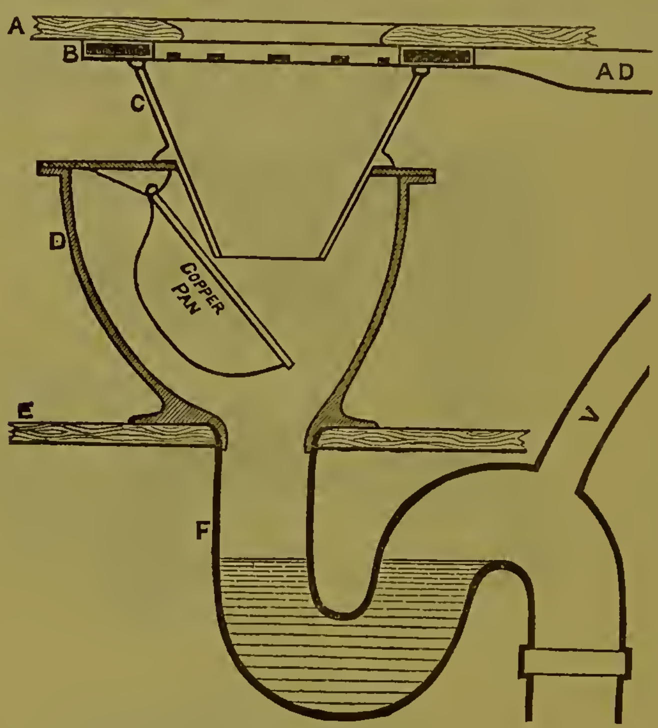

Fig. 19.

from accident, and want of overflow. The earthenware basin C projects into an iron trunk or container D, in which a copper pan works. When the handle is down the pan is full of water, and embraces the projecting extremity of the basin, but on pulling the handle it is removed from the basin, and upsets so as to discharges its contents into the lead trap F below. The faults are the size and shape of the trunk or container, which becomes coated with filth, the hole through which the pin enters it, and the suspicious character of the joint where the basin enters the trunk. In short, the inside of the container is a

receptacle for filth and a generator of sewage gas. A pair of ventilating pipes, connecting the trunk with the external air, mitigate but do not altogether remove this state of matters. Two pipes give a circulation; when there is only one small pipe, the entering current puzzles the outgoing, and the movement is arrested.

An American arrangement for ventilating the basin, and removing foul air rising from the trunk when the pan is lowered, is shown in fig. 19 B *in situ* between the wooden seat A and the

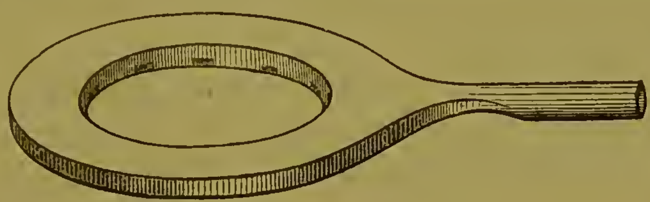

Fig. 20.

basin, and a detached view is given in fig. 20. It consists of a ring of flat tube having perforations to draw in air and terminating in a pipe passing to roof, if possible alongside a chimney, and capped with an air-sucker of some kind. A somewhat similar method is found effective in Holland, in ventilating not only the basins of the Liernur closets, but the closet itself; at least I found dozens of them perfectly sweet, where there was no apparent exit for air except into the basin and up its vent pipe. The lead siphon trap with 1½ inch seal, generally used under water closets by Edinburgh plumbers, holds about 4½ pints, and the copper pan in pan closets holds about the same amount. To flush a closet properly about three times as much water is required as will fill the trap,—one fill to drive out the contents, a second to wash it out, and a third to fill it up coming as after flush; allowing in addition for filling the pan with clean water this gives two and a quarter gallons, or a trifle over the usual amount. The water should be delivered in a body suddenly. A large amount coming through a small pipe is of little use, compared with a smaller body of water delivered *en masse.* When the handle is pulled up many valve closets, which contain a large quantity of water in the basin, are apt to pass the water first out of the basin

into the trap, and the solids last, and unless there is a copious afterflow, delivered through a supply-pipe of unusual size, the solids may not get further than the trap until the next time the closet is used, for want of a sufficient body of water behind them. It is obvious that the chief body of water should follow and not precede the excreta through the pipes. Closets should be supplied from cisterns not used for drinking; and in any case the air-pipe for service-box should either be led outside or done away with, by placing the valve near the closet, so that the pipe may be always full of water. Direct supply arrangements from the mains ought to be strictly prohibited in all places.

The handle should be capable of being pulled when the lid is down; and closets for the use of young females, afraid of the noise of rushing water, as in boarding schools, factories, &c., should work from the seat, as experience shows that they will not flush ordinary closets sufficiently.

Soil pipes are often made too large, and at the same time not ventilated, both at top and bottom. There are in Edinburgh soil pipes of 3-inch diameter that have given perfect satisfaction for more than a dozen years in tall buildings, but most plumbers prefer to make them 4 inches diameter. A larger size than 4 inches is undoubtedly a mistake, but whether less than 4 should be adopted as a general rule I cannot say. A plumber, with large business and long experience, informs me that he has come to the conclusion that iron soil-pipes 3½ inches diameter are best. If a trickle down the narrow soil-pipe in cold weather could manage to choke it with ice, it would do good by forcing attention to bad apparatus. The soil-pipe should be carried to the roof full size, and open freely or with a wind cap, clear of windows, eaves, or chimneys, where gases might find a ready entrance. A pipe less than 3 inches diameter is of little use as a ventilator, on account of the friction of the air against the sides. The foot opening of the soil-pipe is often placed in the discon-

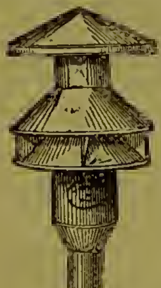

Fig. 21.
Weaver's air-sucker, to cause an up-current in soil-pipes without hindrance to indraught when sewage is passing down.

necting trap, and the current of air sometimes issues from this opening, and when a body of water is coming down the pipe, the air driven before it must necessarily be expelled at the foot opening. Should there be a smell here, it indicates putrefaction in the pipe somewhere, most likely in the trap under the closet. When the foot opening is near windows, &c., Mr Weaver uses an air-sucker to keep the current running up the pipe as far as possible, and therefore entering at this opening. Others put an air-pipe upon the opening, and lead it to the roof to a higher point than the top of the soil-pipe, and make the current run down the soil-pipe and up the air-pipe. This is a good arrangement, but only desirable in exceptional circumstances, on account of the increased friction. The air-pipe should be of the same size as the soil-pipe. Even when there is a separate air-pipe for the ventilators of the branches of the soil-pipe, it is usually best not to connect it with the foot opening. It is seldom good to put a forcing cowl on the soil-pipe, for the tendency of air should be into the pipe and not outwards, in case of defects or of forcing traps. It is, generally speaking, not a good arrangement to make a rain-water pipe even of large size act as air-pipe, or as ventilator to the drain beyond the disconnecting trap; but I see no objection to making the prolonged sink and bath-waste pipe, or perhaps the soil-pipe, act as rain-water pipe. The rain gutter might pour into the side of the pipe through a deep trap as it passed up to the higher part of the roof, but with thoroughly clean and well-ventilated pipes, refinements in the way of precaution are not really necessary.

To sum up.—Our great object is to prevent the formation of sewage gas in pipes and sewers by small size, smooth surface, and free ventilation of the pipes or conduits, with swift flow and complete removal of the sewage; and then to prevent sewage gas generated without from obtaining access to our household pipes of any kind by thorough disconnection; and finally to prevent the liquid or gaseous contents of the pipes from entering the dwelling by good joints, traps, protection against the action of wind, and ventilation.

Water Supply.—I hope that cisterns for drinking-water will more and more become a thing of the past throughout the country. The temptation to leave them uncleaned or uncovered, or to place them where the water can imbibe noxious gases, is too great. The overflow is best carried through the wall as a warning pipe, or made to discharge with much noise into the bath, where the water can be measured. To pass it into soil or waste pipes is very rightly prohibited, though we still have cases of diarrhœa due to that cause in old houses. Fortunately, very few waters except those which are very suspicious from other reasons act dangerously upon lead pipes. It is well to know that if the most minute hole exist in the tin lining of tin lined pipes, the action is more rapid and violent than on common lead. Such piping requires care in the manufacture and testing for holes with salt and water and a galvanometer.

Note.—Among the model bye-laws issued by the Local Government Board is one which, if adopted by any town, would force the inhabitants to ventilate the public sewers through their soil-pipes. It prohibits disconnecting traps between soil-pipe and drain, and prescribes a diameter of *at least* four inches for the soil-pipe, which is to be carried up full bore, without bends, outside the building to open at the roof. To make such an arrangement safe, very good ventilated sewers would be required, and a wise man would have a large ventilating opening in his drain somewhere between soil-pipe and sewer.

LECTURE II.

Ventilation and Warming

Form an extremely difficult subject to treat in one lecture. It is one of great importance, embracing numerous details, and the circumstances of different cases vary so much that no one method of treatment is universally applicable. Moreover, authorities disagree regarding important points, not only with each other, but often with themselves in the same work. I hope, however, that by keeping to fixed principles and well-ascertained facts, I shall avoid stating anything positively erroneous.

The air of a room may be deteriorated in a variety of ways. It may be too moist or too dry; it may have an unpleasant smell, or contain the germs of disease, or merely the effete matters discharged by skin and lungs; but in all cases the cheapest and most effective remedy is to change the foul air for fresh by ventilation, which may be defined as a constant and imperceptible renewal of the air. In ordinary circumstances, purification of air by disinfectants, &c., is labour lost. The proper use of volatile disinfectants as a general rule is the purification of walls, roofs, and furniture.

The composition of the air varies within narrow limits. The principal constituents are nitrogen (which is inert), oxygen (the active principle), ozone in small quantity, carbonic acid gas, and vapour of water, the quantity of the latter depending largely upon the temperature. The purest air contains most oxygen, and ozone, which is merely a very active modification

of oxygen, never present in very large amount. At the same time, the purest air contains least carbonic acid, organic matter, or dust. The following figures show what an enormous influence a trifling difference in the chemical composition of the air exerts upon personal feeling and well-being.

The table is for parts per 10,000:—

	Oxygen.	Carbonic Acid.
Purest mountain air, ...	2099	3
Standard pure air of town and country, .	2096	4
Street air, Manchester, . . .	2094	...
,, Glasgow, ...	2090	...
Eighteen inches below ceiling, in a room with fire and gas lighted, and two inmates, .	2046	69
When a candle will not burn, . .	1850	...

We all know the exhilarating buoyant effect of the air of a Highland hill, and yet how small is the difference, as it appears to the chemist, between it and the worst air that will support life even for a short time!

Carbonic Acid.—A man breathes about fifteen times per minute, discharging 20 to 30 cubic inches each time, so that about 350 cubic feet of air pass through the lungs per day. This air is warmed and saturated with watery vapour, and gains from 400 to 500 volumes of carbonic acid per 10,000 volumes of air, and loses 400 to 600 of oxygen. The amount of carbonic acid is interesting, for several reasons. Each person gives off ·6 cubic foot per hour, or from 12 to 16 cubic feet of this gas in 24 hours, equal to rather more than 8 ounces of carbon. As is seen in the table above, the average amount of carbonic acid is 4 volumes in 10,000 of outside good air, but in respired air it amounts to 448 per 10,000; and it is found that, however often the same air be respired, though it will no longer sustain life, it does not become charged with more than ten per cent. of carbonic acid. Carbonic acid already existing in the air we breathe, resists the out-passage of carbonic acid from the blood, which therefore accumulates in it, and poisons us; but although carbonic acid in larger

quantity is poisonous, yet when it is the only impurity in air, and the oxygen is not diminished, it requires from 150 to 200 volumes per 10,000 to produce the severe headache, sickness, and loss of appetite sometimes seen in well-sinkers, and requires 500 to 1000 volumes per 10,000 to kill. Without doubt, smaller amounts are injurious, but we may safely assume that the effect of less than 10 or 15 volumes per 10,000 is not perceptible, provided there is no other impurity present. An atmosphere rich in carbonic acid is highly favourable to the growth of some forms of fungi, such as the one that causes dryrot.

The real importance of the quantity of carbonic acid in ventilation consists in its being a convenient means of estimating the very poisonous organic matters associated with it. If there is much carbonic acid, there is much other impurity of an extremely deadly character, though it is difficult to estimate the quantity of these organic vapours and particles, and the carbonic acid forms a useful gauge or clock-face to tell their amount. Looked at in this light, 10 volumes of carbonic acid in 10,000 in the air of a room is a large amount, and 72 in 10,000 is the amount in the worst air ever examined by Pettenkofer.

Water Vapour.—The skin and lungs give off 25 to 40 oz. of water in 24 hours, and this alone would require more than 200 cubic feet of air per hour to carry it off as vapour. Dr de Chaumont says, 2000 people give off in two hours 17 gallons of water. An increase of temperature increases the capacity of the air for moisture at a more rapid rate than the temperature rises. For every increase of 27° F. the capacity for moisture is doubled. Consequently a smaller quantity of hot air than of cold would carry away the water vapour.

The organic matter from the skin and lungs is the most important impurity added to air by living beings. It consists partly of vapour and partly of small particles. It is difficult to destroy, is readily absorbed by many substances, and possesses much affinity for water. It is poisonous. If the carbonic acid and water be removed from respired air, the

remaining organic matter will kill a mouse very soon. Breathed in small quantity by men, it causes feverishness, quick pulse, heat, thirst, and loss of appetite. Many of the people who escaped alive from the Black Hole of Calcutta died soon after of putrid fever, or had boils from the effects of the organic matter in the air they had breathed.

Burning gas vitiates a large amount of air. A small burner consuming only 3 cubic feet in an hour will destroy the entire oxygen of 24 cubic feet of air; and if gas is not thoroughly burned, some *carbonic oxide* is formed, which is extremely poisonous, and some of the gas itself may be unconsumed. A gas jet may produce as much carbonic acid in an hour as nine or ten men, but, as already explained, carbonic acid from such a source as this does not mean the same thing as when accompanied by organic matter. Moreover, the light water vapour formed along with it, and the high temperature of the products of combustion, tend to cause a speedy escape if an opening be given. Wolpert says that for each cubic foot of gas burned, 1800 cubic feet of air are required to properly dilute the products of combustion. This would allow as much air for one small burner as for two men.

The effects of breathing impure air are in the lesser degrees well known to all of us. " Our divines from time immemorial have deplored the sleepiness of their congregations, and attributed it to indifference to pulpit teachings, when a little pure air would have awakened the people more effectually than any amount of eloquence." We all know the headaches and heaviness of crowded meetings, and the colds, inflammations, and other illnesses liable to be contracted at them. In the previous lecture I stated that most internal inflammations are due to perverted action of the nervous system, and that this is frequently set up by the application of cold; but healthy nerves are little liable to be disturbed in this way. It is when the vitality has been lowered, and the system poisoned by inhaling the impure air of an evening meeting, that we are most in danger from sudden changes of temperature which

would have little effect had we been supplied with pure air previously.

It is quite common for people to speak of heat as synonymous with impure air, but though, as a general rule, air vitiated by breathing in a building is warm it may be the opposite.

Persons who habitually breathe bad air are pale, weak, have little appetite, and are very liable to scrofula and consumption. Our proofs of this are only too abundant and saddening. In Vienna an ill-ventilated prison during four years had a mortality of 51·4 per 1000 from phthisis, while a better ventilated prison had only a mortality 7·9 per 1000 from this disease. In the Dublin House of Industry scrofula was so rampant as to be thought contagious till ventilation checked it completely. Before the Barracks Commission had given our soldiers more air in their barracks, the illness and deaths from consumption were excessive even in the best climates. Even after the lessons of the Crimean war the death-rate of the whole army in 1858 was 17·5 per 1000, as compared with 9·6 in 1875. The death-rate of the Foot Guards was 20·4 per 1000 in 1858; it was last year 7·72. The deaths amongst them from tubercular diseases have been reduced from 12·53 to 1·69, or less than one-seventh of the former mortality. New hospital accommodation, provided on the old experience of sickness per 1000 of force, has been found to be in excess to more than double of what is now required. On foreign service the same state of matters is found. At Gibraltar, during peace from 1818 to 1836, the death-rate was 21·4 per 1000, as against 5·5 per 1000 in 1875. But there is no need to multiply instances of reduced death-rates. It is not merely a question of living or dying, but of our kind of living. If we are to feel well and vigorous, to take pleasure in active work, to be laid aside few days in the year by illness, then we must have plenty pure air.

Hourly Air Supply necessary.—This leads to the question, What is a sufficient supply of pure air? which can only be answered by considering the quality. The carbonic acid of standard air averages four parts in 10,000, and many inquiries by competent men have led to the conclusion that the air of

a room should not contain more than six volumes of carbonic acid in 10,000, *i.e.*, the original 4 volumes and 2 added by respiration. When the carbonic acid (or in chemical symbols CO_2) exceeds six volumes in 10,000, the accompanying animal matters are perceptible to the sense of smell. Eight to ten volume air is close and stuffy, and above ten it becomes foul and offensive, while our sensations no longer form a trustworthy guide as to the extent of pollution.

If we lived in a current of air which reached us pure and at once escaped by an outlet, it is obvious that a small allowance would suffice. We should in that case breathe four-volume air, and would care little whether it had become six or twelve volume air when it left us. Fig. 1 will help to explain this. The X represents a man sitting in a large pipe,

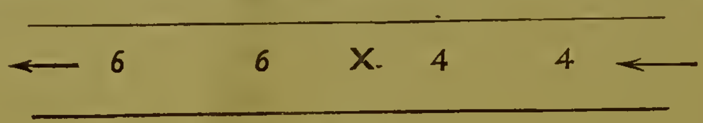

Fig. 1.

through which 3000 cubic feet of air per hour is passed. It reaches him as four-volume air, but leaves him as six-volume; and supposing the quantity reduced, it would still reach him and be inhaled as four-volume, though it might leave him as eight or ten volume. Usually it is not possible to live in a steady current that does not touch a second person after leaving the first; and fig. 2 represents a room with one inmate into which standard air is continually entering and mixing with the air already in the room, from which an equal amount escapes by the outlet. As each individual emits ·6 of a cubic foot of carbonic acid per hour, 3000 cubic feet of four-volume air must enter per head per hour to keep the air in the room at six-volumes when mixing takes place, and if less air be passed in, the rise in the proportion of carbonic acid will indicate the deterioration of quality. In the case where

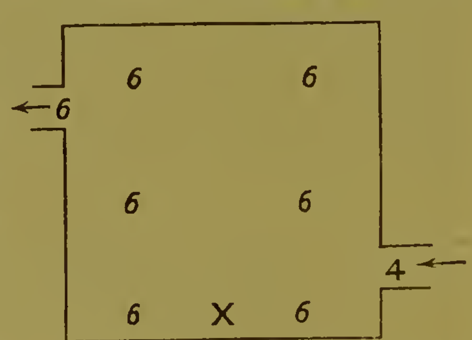

Fig. 2.

3000 cubic feet of four-volume air per head is supplied through the inlet, it is obvious that the inhabitants breathe and live in six-volume air. The following table indicates the condition of the air in a room with different rates of supply per head per hour:—

Amount of Standard Air necessary to maintain CO_2 at		Area of Inlet required to supply the different amounts at a speed in the Inlet of		
		$1\frac{1}{2}$ Feet per Second.	$2\frac{1}{2}$ Feet per Second.	5 Feet per Second.
6 vols. in 10,000,	3000 cub. ft.	80 sq. in.	48 sq. in.	24 sq. in.
7 „	2000 „	$53\frac{1}{3}$ „	32	16 „
8 „	1500 „	40 „	24	12 „
9 „	1200 „	32 „	$19\frac{1}{5}$	$9\frac{}{5}$ „
10 „	1000 „	$26\frac{2}{3}$ „	16	8 „

These circumstances show the advantage current ventilation has over the mixing method, especially in crowded meetings, by allowing the total quantity of air to be reduced without detriment. The difficulty of avoiding draughts and preventing the impure current from touching a second person, as well as the great liability to disturbance from wind, renders this kind of ventilation seldom practicable. Mr Weaver, however, writes me that by a careful arrangement of openings in rooms he has often succeeded in giving perfectly good ventilation with less than 1000 cubic feet per head per hour. When the entering air is warmed previous to admission it is much less likely to be felt as a draught. The following table is compiled from Parkes' " Hygiene," to show what currents are perceptible :—

Temperature 55° *F. to* 60° *F.*

$1\frac{1}{2}$ foot per second is perceived by			none,
2 feet	„	„	some,
$2\frac{1}{2}$ „	„	„	some,
3 „	„	„	most,
$3\frac{1}{2}$ „	„	„	all.

Any greater speed is felt as a draught. At a lower temperature currents are more readily felt, and at a temperature of 70° F. they are less perceptible.

The purest air is required for study or intellectual work of any kind. The brain succumbs to the poisoning influence of bad air before any other organ, and labour becomes a weariness to it, while the muscles are still vigorous. I look upon ill-ventilated schools as a positive cruelty, as well as an injury to health. During sleep pure air is likewise very desirable. The quantity of oxygen taken into the body at night is greater than by day, and we should remember that organic matter in the air destroys much of the active oxygen. It is difficult to enjoy sound and refreshing sleep without abundance of air of good quality, for the same reason that persons with weak hearts are wakeful, viz., want of sufficient oxygen going to the brain. In the latter case the heart cannot drive enough oxygen-carrying blood to the head, and in the former the whole body wants. For intellectual work 3000 feet is imperative, but for mechanical work 2000 is a fair supply, with a walk in the open air after working hours. Dr Wilson, in his charmingly written "Handbook of Hygiene," tells of one English prison where half the prisoners were supplied with seven-volume air, while the other half, though only in their cells by night and at meals, showed by their less robust and more pallid appearance, the effect of the ten-volume air they breathed. Miners are well aware that the amount of work performed is diminished unless the supply of air is free.*

* The general opinion among engineers and architects is very far from agreeing with the data here given. In a paper on "Ventilation of Buildings," read before the Society of Civil and Mechanical Engineers, and published by Spon, it is said—"We thus see that to be in good health a man must have 215 cubic feet of air per hour for his own use. Sick persons require very much more than this." "In a room of the nett cubic capacity of 3800 feet, having a fire burning, inhabited by say six persons, and lighted by three gas lights, there will be required every hour, so that the inmates may be healthy, 1694, or say 1700 cubic feet, of fresh air at 60° F." With such limited ideas it is not surprising to find engineers engaged in elaborate calculations as to how much larger outlets should be than inlets, in order to allow for the trifling expanse in volume due to the warmth of the house. The common opinion of the profession, as proved by the statements in the 17th edition of "Molesworth's Pocket-book of Engineering Formulæ," and the last edition but one of Hurst's equally good and deservedly popular "Architectural Surveyors' Handbook," is that 4 feet per minute, or 240 feet of air per hour per head, is the correct amount. The author of the second edition of the "Engineer's Practical Guide for Fixing Hot Water Apparatus," &c., is so impressed with the importance of ventilation that he goes out of his way to say—"Experiments have been made

Test.—Dr Angus Smith gives a ready test of the quality of air which is worth telling.

Half an ounce of lime water shaken up in a ten and a half ounce bottle filled with air of the room to be tested gives no precipitate with six-volume air, and the same quantity of lime water in an eight-ounce bottle gives no precipitate if the air be purer than eight-volume.

Temperature.—The air supplied in the smaller class of houses should be more or less warmed, for people will prefer being poisoned comfortably to thriving in cold air. Parkes states that "it is impossible to have efficient ventilation in cold weather without warming the air." General agreement points to a temperature of from 60° F. to 65° F. as most comfortable, but our arrangements should permit of warming rooms considerably higher in case of illness. The temperature is, to some extent, a matter of taste for healthy people. Those who are neither old nor very young, who are well clothed and well fed, and have sufficient exercise, require less warmth. The moisture in the air bears upon the temperature. The highest limit for good ventilation at 62° F. is 4½ to 5 grains per cubic foot. Much water vapour in the air makes it feel chill, and we instinctively raise the temperature. In ill-ventilated rooms there is always excess of moisture, and the inmates, if able, always keep a larger fire and warmer room than with good ventilation.

The Marston Salt Mine, in Cheshire, shows the effect of damp air in a curious way. The temperature is almost uniformly 54° F., but visitors feel it chill, and are inclined to pull up their collars. The workmen, on the other hand, are stripped, excepting trousers and boots, on account of the very slow evaporation, which makes them feel the heat of exercise as

establishing that each person will require four cubic feet of air per minute, and each gas light the same," ". . . showing that in three-quarters of an hour the whole of the air has been breathed or consumed; and unless there is ventilation to let out the air, now become nitrogen gas, and an inlet for fresh air at the bottom of the room, the occupants are being slowly poisoned." Our sole defence against the results of such ideas and calculations has hitherto been porous walls and ill-fitting doors and windows, for which we owe true gratitude to the ordinary artizan.

persons never do in a drier atmosphere. Warming the air would make them put on their coats, by increasing the capacity of the air for moisture, and so quickening the evaporation and consequent cooling of their bodies.

Methods of Ventilation.

We may now consider the manner in which the large amount of air required is to be supplied, and we see at once that it must be in such a way that the fresh air coming in shall be thoroughly well mixed, so that the temperature and composition may be as uniform as possible throughout. It may occur that a room is ill-ventilated while a large stream of air is passing through it, entering by one opening and leaving by another without mixing. The size of the room, or rather the cubic space allotted to each person, is very important as regards this point. It is difficult to give a large supply with small cubic space. The entrance and exit openings are so near each other that there is a risk of the stream simply passing straight from the one to the other, and in any case there must be a more rapid motion of the air in the room. A movement of air at 50° F. of more than 6 feet per second is intolerable, and still more so if damp or colder. To pass 3000 cubic feet through a room of 1000 cubic feet capacity, the air has to be changed three times in an hour, and it is found that this rate, or a little more, gives no objectionable draught; but changing the air five times per hour renders a room cold and draughty. Now a five-time change corresponds to 600 cubic feet of space per head, which would thus seem to be rather small; while 800 to 1000 cubic feet of space per head demanding only a three or four time change, is ample. Our inlets and outlets should be small and numerous to give thin streams of air. Large volumes take a long time to subdivide and mix. I worked some years in a room with a fire at each end, and a ventilating opening two or three feet diameter in the roof, intended to give exit to foul air. The fresh air entered at this opening, and descended as a sharply defined column till it reached the floor, when it subdivided and passed off to each fire.

The space above our heads may be looked upon as a mixing

chamber, into which fresh air can be brought to be broken up and warmed before reaching us, and therefore, as a general rule, both outlets and inlets should connect with it.

Natural Ventilation.—In most houses no provision is made for ventilation, and all there is takes place by diffusion or suction through chinks and porous walls. The passage of air through walls and building materials has attracted great attention since the experiments of Pettenkofer have become popular. I have been shown party walls left exposed for some time, where the brick-work near the fireplaces had to be coated with cement on the outside to stop draughts, and you see that it is possible to bring air through the mounted bricks and cylinders of mortar on the table. On repeating Pettenkofer's experiments with these mortar cylinders, I find it impossible to bring or send air through them at anything like the rate described by Pettenkofer. It may be because they are made of slater's mortar, which is very rich and good. In any case, the amount of such ventilation taking place through our two-feet-thick stone walls in Edinburgh is not worthy of consideration, and elsewhere, in villas with exposed thin brick walls, it should be considered whether the wall in general is the most desirable inlet. Wind blowing against a wall, or great differences between external and internal temperatures, promote this kind of ventilation very much. It may be useful to remember that porous walls must in time become saturated with putrefying organic matters, which diffuse to a trifling extent, if at all, although the carbonic acid passes out. The objection to walls of impervious material, because they show wet on the inner surface, seems to me founded on an erroneous explanation of the cause of the wet. It is supposed that porous walls absorb it, and pass it out to the open air. The true explanation is, that walls of impervious material being good conductors of heat condense the moisture on the inner surface by their coldness; while porous substances, being bad conductors, do not condense the watery vapour. This defect is easily remedied, by lining impervious walls with a layer of cork, which has been applied with complete success for this purpose in some of our ironclads. The ventilation should also

be looked to when there is so much moisture in the air that slight cooling condenses it.

The ventilation of a room presents totally different conditions in summer and in winter, with gas lighted, or with open fires.

In summer the mixing of eold air is less important, and we may let it in by open windows; but as there is no warming apparatus at work, exeept the bodies of the inhabitants, there is less tendeney to movement. The first summer that Professor Huxley leetured here, instead of Sir Wyville Thomson, there were frequent eomplaints among the students of the difficulty of keeping awake at his leetures from bad ventilation, though the ehemistry elass-room, in which they met, was found eomfortable and well-ventilated in winter by its ordinary oceupants. The explanation is, that in winter energetie ventilation was eaused by the volumes of warm air poured in from the warming apparatus, and as this was wanting in summer, alterations had to be made to meet the requirements of the Natural History Class.

The outlets in summer should be placed above, either into a separate foul-air flue, or into the chimney near the ceiling. Stoneware foul-air flues are now provided alongside the ehimney in many new houses, and double piping, to serve for both ehimney and flue, is sold. A simple funnel spaee left in the wall when building is not so good. The roughness greatly retards the eurrent of air, and the wind may blow through the wall into the flue to sueh an amount that a brisk current may issue from both upper and lower ends at the same time. To prevent baek smoke or reflux of smut-laden air through these openings valves are neeessary.

These valves should, of eourse, act silently and promptly, and cause as little obstruction as possible. For foul-air flues I do not know a better than the eheap eloth valve made by Crossley of Brighouse (fig. 3). It is quite silent so far as my experienee goes. Aecording to my experience, no valve perfeetly silent in all eireumstances has

Fig. 3.

yet been devised for openings into the chimney. Boyle's mica-flap valves, made by Comyn, Ching & Co., which at first sight appear all that could be desired, make a noise greater than could be supposed when a sharp reversal of the direction of current takes place. They, moreover, require the valve tray to be carefully cemented or puttied into the frame before it is fixed in the opening truly plumb.

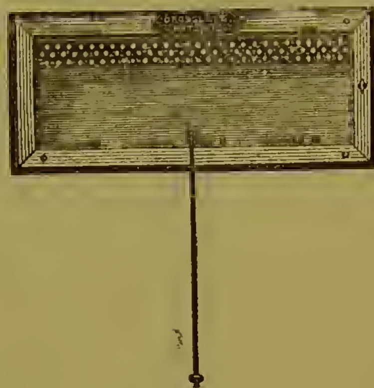

Fig. 4.

Crossley's improvement on the Arnot valve (fig. 4) is generally noiseless; but its defect is that by using both a cloth and a balanced valve it impedes the air-way, and consequently a large size should be chosen. It is cheap, easy to fix well, and commendable. Mr Weaver of Clapham has devoted much attention to ventilation, and invented many arrangements, a few of which are figured. His outlet valves, intended either for chimneys or foul-air shaft, are balanced, and give a clear air-way. I have only experimented with his cheaper forms. Their defects are, that

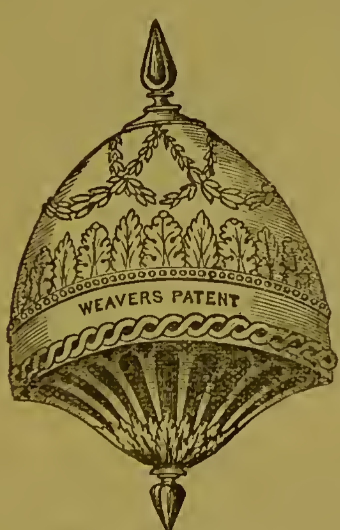

Fig. 5. Elevation.

Fig. 6. Section.

Weaver's *Efflux* Carton Pierre Ventilator.

they are not so free from noise as is desirable, and that careless handling or placing is apt to destroy the sensitiveness, which

in some of my specimens is small enough. Those who object to the appearance of ordinary outlets can have them cased in

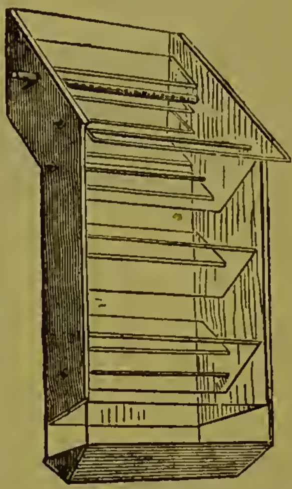

Fig. 7.

Fig. 8.

Carton Pierre, made to suit the furniture, as in figures 5 and 6. Where the air is so smoke and dust laden that it is desirable to wash it, Weaver's inlets for this purpose, shown in figures 7 and 8, are useful. The Purified Air-Ventilating

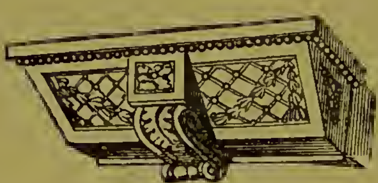

Fig. 9.—Elevation.

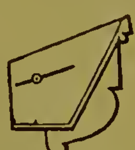

Fig. 10.—Section.

Weaver's *Influx* Carton Pierre Ventilator.

Company, by means of deflecting plates, causes the air to impinge upon the surface of water in a box before being passed into the dwelling through a vertical tube, but the washing is not so thorough as in Weaver's arrangement.

In winter, whether we have a fire lighted or not, we require to avoid contact with rapidly moving air, and therefore inlets should discharge towards the ceiling to allow diffusion and gentle descent of the air in the room. Among direct inlet arrangements for cold air, the cheapest is that termed Costless Ventilation, by Dr P. H. Bird. The lower window sash is raised two or three inches, and the opening filled up with a piece of

wood which keeps the window permanently up. As the meeting rails, where the upper and lower sashes come together, are in this position not opposite to each other, a space is left between them through which a stream of air enters. The stream of air is often not quite vertical, and the action of this inlet is spoiled when window blinds are down. On special occasions demanding a large supply, Dr Bird proposes to throw up the lower sash and suspend a sheet of calico as a valve opposite the opening. The calico does not hang vertically; the lower edge is attached to the sill, while the upper edge slopes inwards to the room and is attached by its corners to hooks in the shutter case, and therefore at some distance from the glass of the window. The effect is to admit a large volume of air with an upward tendency, and at the same time to prevent outsiders seeing through the opening.

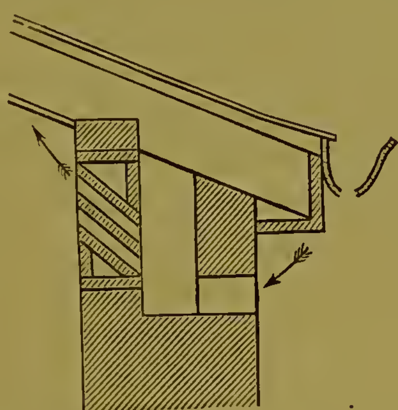

Fig. 11.—Jenning's air brick.

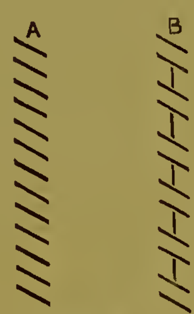

Fig. 12.

To supply large temporary requirements some persons remove the upper sash and replace it by a board or tense sheet of some kind of the same size as the sash, sloping into the room at an angle of about 30 degrees, so as to shoot the air towards and along the ceiling. In the absence of wind this is a very effective arrangement for crowded evening receptions. The well-known Sheringham valve is arranged upon similar principles. A pane of glass is hinged at its lower edge, and can be made to fall inwards between side screens at the upper edge. When the pane is vertical, there is no opening, but on allowing it to fall inwards, an opening is formed and

the incoming air is thrown, fountain-like, towards the ceiling. Jenning's air brick gives the air a similar direction, and is used for admitting the cold air into barracks. It is placed about nine feet above the floor level. Glass louvres, in which a pane is replaced by strips of glass arranged like a Venetian blind (fig. 12, A), are often seen. The effect is very much the same as that of a Sheringham valve, and in small rooms a cold draught is always caused, for the streams entering between the strips of glass at once coalesce and form a large column of air that would require much space to properly break up. If the strips were placed so that each alternate one was vertical, the incoming streams would be separated by layers of still air, and soon mingle. Fig. 12, B represents this arrangement in a diagramatic way, and not quite as it would be in practice. Vertical pipes form an excellent means of air inlet. They are patented by various persons, *e.g.*, Tobin of Leeds, Shillito & Shorland of Manchester, and The Purified Air Company of London; but they do not appear to be a recent invention, and it is difficult to see where the difference between the patents lies. The Purified Air Company passes the air over the surface of water; and to Mr Tobin undoubtedly belongs the merit of drawing public attention on a large scale to the virtues of these pipes, and to the advantage of not carrying them up too near the ceiling, and so allowing the speed to be gradually lost before the air reaches it, and thus preventing rebound.

Direct *horizontal* inlets from the outer air, such as perforated window glass, gauze screens across openings, "hit or miss" slides, and holes, are much inferior to those already mentioned, and are especially objectionable when placed less than seven feet above the floor line. A little consideration will show that wire gauze does little or nothing to break up the entering current of air, the openings being so little separated from each other that the entering streams at once rejoin and form one current. Undoubtedly, fine wire gauze lessens or prevents draughts, but it is because the great friction in the small openings reduces the quantity of air passing through to an insignificant amount. Ventilation by Watson's siphons, now carried on by Hill and Hey of Halifax, in conjunction with cowls under the name of Excelsior system, has been applied

with success in many instances, though I am far from agreeing with the manufacturers that it is the best in all cases. The inlet and outlet are both at the ceiling. Mr Watson took advantage of the circumstance that an in-current will usually be set up in one-half of a tube, divided by a partition into two (fig. 13), and an out-current will be set up in the other; whereas if the partition be withdrawn, the one current counteracts the other, and movement is arrested. Valves and deflecting plates are employed to regulate the in-draught. M'Kinnel's plan of placing an efflux tube within an influx tube is better. The outlet tube is longer than the other, and projects through the ceiling further into the room, where it carries a deflecting plate to spread the entering air of the influx tube along the ceiling, and prevent it from passing directly to the outlet. A pipe passing along in the cornice, divided into an upper and lower channel by a horizontal partition, and perforated with small holes, has been found a good means of inlet and outlet in many cases. The lower channel is the inlet, and the upper or outlet channel is connected with a foul-air shaft or other outlet. This arrangement, devised by Potts, has been found very useful in schools and other buildings where ventilation had originally been neglected.

Fig. 13.

The varying action of the wind has such a disturbing influence, that whatever form of inlet is adopted, arrangements must be made for modifying and controlling the current, whether by valves or otherwise. If inlets open from a tube passing right across to connect with both windward and lee-ward sides of the house, there is less disturbance from wind.

The best positions for the inlets in a room depend upon so many circumstances, such as the shape and size, external walls, windows, &c., positions usually occupied by the inmates, course of currents and eddies from inlets, fire, and gas, that a careful study of each apartment should be made; and in this lecture it is impossible to do more than make some passing allusions.

In a church, a pipe perforated with pinholes, or composed

of fine wire gauze, and placed under the book-board, would supply air at the breathing level, and yet not cool the lower part of the body. With an exit above, this would be an instance of current ventilation, and the supply might be so reduced that it could be warmed to 55° F. or 60° F., and issue very gently from the pipe.

Outlets.—In addition to the arrangements already mentioned, cowls and other appliances for taking advantage of the wind to create an updraught have been loudly praised. Of cowls we have an endless variety contrived by inventors, from Banner to Boyle. As yet, no experiments by competent neutral persons have been made upon the air-sucking powers of these cowls, so that I am unable to give much advice about them. During fogs and calms, when we are most in need of assistance for our ventilation, these cowls, one and all, do positive harm, by retarding the current due to differences of temperature; but even with wind, I suspect they render less assistance to the natural up-current in the pipe than they are credited with. Dr Burdon Sanderson found that in ventilating the Liverpool sewers the Archimedean screws added only 20 per cent. to the natural discharge of air. Cowls (not excepting Boyle's) do not prevent those occasional reversals of the direction of current where inlets become outlets and upcasts become downcasts, which we find in all ventilating arrangements. Only three or four days ago, I saw smoke and flame violently blown away from the mouth of a forcing cowl on a short pipe, which, after descending to the ground, passed to the roof ridge, and terminated in an Archimedean screw cowl in rapid motion at the time. This action lasted about a minute, and very much astonished the person who brought me to see the arrangement, as he had just before been declaring the impossibility of such an occurrence. We must then be prepared for occasional reversals of current.

Windows should, if possible, be arranged so as to take advantage of the wind, and secure a thorough blow through, and sweeping out of the air. Hence the value of cross windows in hospitals and large rooms, and one reason why all windows

should open from the top as well as at the bottom, and extend well up towards the ceiling.

With a fire burning the practical problem of ventilating in a rough way is greatly simplified. The outlet is low down, and if air is freely admitted and jetted upward there is good and gradual mixing. An ordinary fire will extract from 6000 to 20,000 cubic feet per hour, and not only will it overmaster all other outlets, reversing the current in them, but it will often draw in sewer air unless the inlets are sufficiently large. Insufficient inlets are often a cause of smoky chimneys; a current of air is established down the chimney either to feed the fire below or to supply a previously lighted fire in some other room which, by reason of its hot chimney, has the advantage of those recently lighted.

Open fires, of which there are two kinds, differ from stoves in that they admit much air into the flue or chimney beyond the amount required for combustion. The common form warms almost entirely by radiation, and as the heat decreases as the square of the distance, an object ten feet from the fire receives only one-hundredth part of the heat that it does at one foot distance. Radiant heat has little effect upon the air of an apartment, but warms the walls and furniture, and the pleasant sensation of being surrounded by warm objects, with comparatively cool air, may help to account for the extraordinary persistence with which we have adhered to the common open fire, notwithstanding disadvantages which ought to have banished it long ago from the houses of all who cannot afford unlimited cubic space for dwelling room, and to whom the price of coal is any consideration. The common fire utilises only ten per cent. or a little more of the coal, and heats a room so irregularly that the thermometer may indicate a difference of many degrees between opposite parts; and, as we usually see it, the best and purest air is carried away by the fire, and warmed after it is lost to us instead of before it reaches us. The cold draught passing from under the door or other low inlet chills the feet so much as to be not only disagreeable but at times dangerous. The currents caused by a fire are shown in figure 14, where W indicates a window, F

the fire, and V a ventilating opening. Some of the air is drawn into the chimney; another portion is warmed, ascends to the ceiling, and, on coming near windows or cool walls, again descends to the floor and passes towards the fire, thus establishing a constant circulation which is decidedly useful. Cold air can generally be best admitted near the fireplace, so that it may mix with the warm air. If admitted at the distant end of a long room it increases the natural disparity of temperature; in this case the inlets may be placed near the fireplace end, but on opposite sides of the room, so that the in-currents may cross the main circulation.

The front fire grate, or country parson grate, made by Barnard, Bishop, and Barnards, of Norwich, very greatly increases the amount of radiation, and is extremely cheap. The fire trough is high and wide, but shallow from front to back ($4\frac{1}{2}$

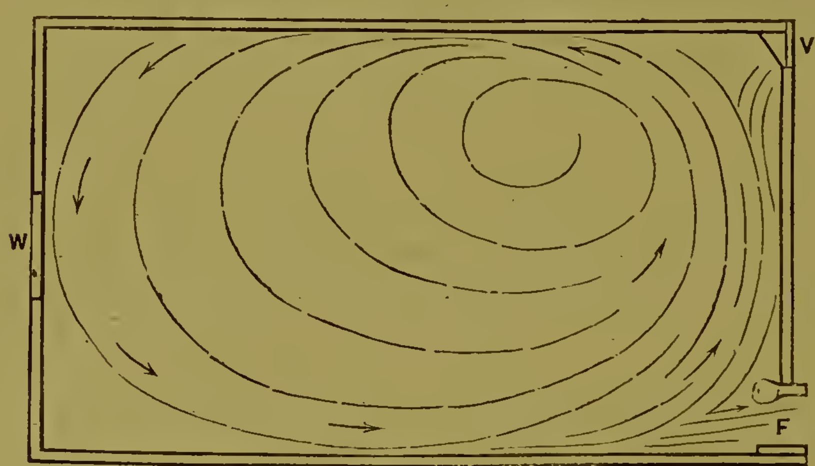

Fig. 14.

inches below and $5\frac{1}{2}$ inches at the top), and the fire is in contact with fire-brick, not only at the back and sides, but it rests upon a slab of the same material, so that no air enters from below, and combustion is confined to the surface exposed to the room.

To ensure perfect combustion, little heat should be abstracted from the burning coal, but the hot gases resulting made to yield up as much as possible. Firebrick is a good lining, because it carries away heat slowly and radiates it well into the dwelling. A thin and small fire which would soon be

extinguished by the conductivity of metal will flourish in contact with firebrick, and the coal will be converted into carbonic acid and water, instead of half passing away in smoke and carbonic oxide without yielding up its heat.

The second kind of open fire is that known as "Ventilating," and it is one which I trust will more and more come into use. Many inventors have been at work upon them, and details differ, but the feature common to them all is a chamber behind or around the fire and foot of chimney, into which external air is led to be slightly warmed and then passed into the apartment by openings above the mantlepiece or on either side of the fire. The temperature all over a room with a grate of this kind is remarkably uniform and comfortable, draughts are not felt, and about one-third, or a little more, of the value of the coal is utilised. The strongest argument in their favour is that without air-warming the occupants of houses with limited cubic space never will suffer really effective ventilation, but will to a certainty stop up the inlets. "Half the inlet air is warmed in barracks (area of tube = 6 square inches per head), and the other half comes direct from the outer air through Sheringham valves." Captain Galton's well-known grate is used in barracks, and it is very good. Messrs A. Steer & Co., of Queen Victoria Street, London, make these grates to stand out into the room instead of being recessed in the wall, and thus gain radiation from the sides. Messrs Shillito & Shorland, of Manchester, are good makers of different varieties of ventilating grates and stoves, but they generally warm the air a little too much. It is best to pass in a large volume only slightly warmed, for otherwise the humidity becomes a troublesome question, and the disagreeable smell of a stove is perceived. Whitwell's "Save-all-waste" grate, made by the Coalbrook-Dale Company, is a most efficient warmer, but unless extreme economy of fuel is required I prefer the less complicated arrangements of Shillito and Shorland. I am not altogether satisfied with the prices or patterns of any of the firms known to me, and think there is room for any person who would supply middle class and poorer houses with cheap grates that would take the chill off a large volume of entering air. In towns, some kind of strainer to remove smuts and

dust is of use when the entrance tube to the warming chamber is correspondingly enlarged to compensate for friction.

Unless in apartments where thorough artificial ventilation is carried out the fire should never have a separate air supply for itself, for otherwise it ceases to ventilate the apartment.

Of all methods of ventilating and warming middle-class houses in a hygienic point of view, I think there is nothing better than that of a ventilating stove (not ventilating open fire grate) in the hall or lobby, to fill the staircase and passages with pure warm air, which can be let into the rooms by openings in doors or walls easily concealed by pictures. I am sure that many invalids who go abroad to shiver during every cold day over two or three sticks called a fire in rooms specially constructed to be cool, would be much better off within their own solid walls, and enjoying home comforts, were they given the equable temperature and range of the entire house permitted by lobby warming. You may remember that during the severe frost three years ago the death-rate of Edinburgh and Glasgow went up to more than double the ordinary rate, while that of the lunatic asylums were not affected in the least. In one asylum this was accomplished by the simple plan of hanging thermometers on the doors of the wards, and telling the attendants to heap more coal upon the fire in the passages whenever the thermometer fell a degree.

Gas warming, as usually carried out in shops by stoves without chimneys, is most pernicious. Bond's gas stove, or George's calorigen, are good and safe, and utilise a large percentage of the value of the fuel, which is, however, much more expensive here than coal. If a gas fire ever is cheaper than coal it must be owing to its cleanliness, freedom from trouble, and adaptability.

Gas lighting as usually seen completely destroys the circulation of air caused by a fire, and figured on page 52. It causes an accumulation of the products of combustion and spoilt air at the ceiling of such a high temperature as seems incredible to one who has not stood upon a table or steps to hang a picture or do something near the ceiling at night. An outlet leading to a foul-air flue or into the chimney, as previously described, is necessary unless ventilating sun burners, which

have been much improved by Strode & Co., of Osnaburgh Street, London, or Ricketts' ventilating globe lights are used. These require to be cautiously applied for fear of overdrying any woodwork too near the pipes carrying off the hot products of combustion. Ricketts' ventilating globe lights are expensive, but they help to ventilate the room, and are not unsightly. A ventilating ceiling centre flower is sometimes used to conceal the orifice of a flue for the air spoiled by gas, and acts well if protected against wind. In our new Infirmary every gas jet is armed with an inverted funnel terminating in a pipe which passes to foul-air flues in the walls, so that lighting the gas will actually improve the ventilation instead of spoiling it. In barracks no foul-air shaft is made of a larger area than one square foot, and about twelve square inches of foul air flue and six square inches of chimney is allowed for each man. Bends and great length cause considerable diminution in the quantity discharged by such shafts, and about one-fourth or more is added to the calculation to allow for friction. The movement in chimneys and flues is simply due to the lightness of warm air, and can be readily calculated when we know that each increase in temperature of one degree Fahrenheit causes an increase in bulk of $\frac{1}{491}$ of the volume at 32° F. Supposing that when it is freezing outside a chimney 50 feet in height has a temperature of 141° F., then the weight of this column of 50 feet (or 600 inches) of hot air would be balanced by 40 feet 11 inches (=491 inches) of cold outside air, and the weight of the remaining 9 feet 1 inch would force air through inlets and up the chimney. The rapidity of flow would be eight times the square root of this head of 9 feet 1 inch, or a trifle over 24 feet per second. The usual rule given by engineers is not quite correct, because it measures the head in warm air instead of cold, but it serves well enough in ordinary practice when the difference of temperature is not great.

It is—The height from inlet to opening from which air escapes multiplied by the difference of temperature between outside and inside, and divided by 491. The square root of the result multiplied by 8 gives the velocity in feet per second. To get a more exact answer we must divide by 491 plus the difference of temperature, take the square root of the result, and multiply

by 8·025. Thus in the example already given the height from inlet to escape opening is 50 feet, and the difference of temperature is 109 degrees: then

$$\frac{50 \times 109}{491+109}=9{\cdot}0833 \text{ height of head;}$$

and velocity $=8{\cdot}025\sqrt{9{\cdot}0833}=24{\cdot}18$ feet per second.

These rules merely give the theoretical velocity, which, on account of friction and eddies, is always considerably in excess of the actual velocity, and requires deductions of one-fourth to one-half. Indeed, if 5 be substituted for 8 as multiplier in the rule, it will give a result which will generally be more in accordance with experiment. "In the experiments of the Barrack Commissioners, the chimney discharge ranged from 5300 to 16,000 cubic feet per hour, the mean being 9904. The usual current in a sitting room chimney with a fair fire measures 3 to 6 feet per second, and may rise with a very large fire to 8 or 9 feet."

Watt Institution and School of Arts.

ABRIDGED SYLLABUS OF THE COURSE OF LECTURES ON SANITATION.

In this Course of about Twenty Lectures it is intended to point out the principles which guide us in selecting or devising Sanitary arrangements and appliances, and executing work so as to promote health. The Course is addressed specially to architects and tradesmen engaged in practical work; and the chief sanitary inventions will be described in detail and criticised. Numerous experiments, drawings, and specimens are exhibited in illustration of the Lectures.

WATER SUPPLY.—Amount required—quality—prevention of contamination at source, in carrying, and in distribution—head and reservoirs—constant and intermittent supply—material and lining of pipes—action of subsoil on iron—of different waters on lead—position of pipes—conditions of intake of gases or liquids from surrounding soil—cisterns—overflows—valves—cocks—regulations of water companies—meters—detection of waste—hardness—filters and filtration.

DWELLINGS.—Site—aspect—dryness of site—isolation from soil—damp proof courses—walls—arrangement of rooms—drying new buildings.

VENTILATION.—Composition of air—impurities added—amount required for breathing—gas—fires—cubic space and ready methods for measuring—circulation of air—inlets—outlets—air shafts—ceiling—floors—valves, by different makers—tubes—whole house systems—ventilating cowls and fans—air cleaning.

WARMING.—Principles of good combustion and proper air warming—open fires and varieties of them—stoves for gas, for coal—ventilating stoves and fire-places—hot water, high and low pressure—steam—smoky chimneys.

BATHS.—Position—size—inlet—outlet—valves—hot water from kitchen—different patent and other systems.

GAS.—Arrangement of pipes—testing pipes—combustion—burners.

REMOVAL OF WASTE.—Slop sinks—kitchen sinks—material and position—contraction and expansion of metals—joints—traps and trapping.

Dry earth closets—charcoal closets—ash closets—tub systems, with numerous examples of each.

WATERCLOSETS.—Shape and size of basin—hopper closets—wash-out closets—trapless closets—valve closets—pan closets—ventilation and position of closets—amount and mode of water supply—water waste preventers and meter valves—closet mechanism.

SOIL PIPES.—Position—material—size—ventilation—rate of flow—disconnecting traps at junction of house pipes with branch sewer.

HOUSE DRAINS.—General arrangement of house pipes—systematic inspection of a house, and methods of testing.

SEWERS.—Material—shape—size—inclination—workmanship.

DISINFECTION and DISINFECTANTS.